U.S. ARMY TOXIC AND HAZARDOUS
MATERIALS AGENCY

HOT GAS DECONTAMINATION PROCESS FIELD DEMONSTRATION
SITE SELECTION REPORT

by

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Advanced Development and Field Testing of Novel Processes
to Decontaminate Chemical-Agent-Contaminated Facilities

TASK ORDER NO. 3
Demonstration of the Hot Gas Decontamination System for Chemical Agents

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INTRODUCTION

As part of its Installation Restoration Program, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) is investigating new and innovative ways to decontaminate chemical-agent-contaminated structures. The objective of this program is to develop techniques to meet future requirements to decontaminate facilities previously used for the manufacture, testing, storage, and disposal of chemical agents. Facilities of concern include building structures, above-ground and underground storage tanks, process equipment, sumps and piping.

Laboratory development and pilot testing has identified the Hot Gas Decontamination Process as a treatment technology for decontaminating structures. The process involves the in-situ heating of a structure by burner exhaust gases. The volatilized contaminants are subsequently destroyed in a downstream afterburner. When the technology is fully developed, the Hot Gas Decontamination Process may provide an acceptable, non-destructive alternative to the Army "5X" regulatory requirement for release from government control without precautions or restrictions (incineration of agent-contaminated material at 1000°F for 15 minutes)[1]. The process can also, as a safety measure, provide a measurable reduction of risk before full-scale incineration is performed.

A pilot test of the Hot Gas Decontamination Process was successfully conducted at Dugway Proving Ground in July 1987[2]. A test structure with various types of building materials (concrete block, poured concrete, and steel plating) was spiked with known amounts of distilled mustard chemical agent (HD) and subjected to the treatment process. Monitoring of the

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1 U.S. Army. 9 October, 1987. AMC Regulation No. 385-131, Safety Regulation for Chemical Agents H, HD, HT, GB, and VX.

2 McNeill, William, et al. October 1987. "Pilot Plant Testing of Hot Gas Building Decontamination Process." Battelle Columbus Division for U.S. Army Toxic and Hazardous Materials Agency, Report AMXTHTE-CR-87130.

effluent stream revealed that the HD was volatilized from the surfaces and removed by the hot gas stream. Analysis of the structural materials after the test showed no residual HD contamination.

The next step in the development of the Hot Gas Decontamination technology is to conduct a full-scale demonstration at an existing installation. Rocky Mountain Arsenal, Colorado (RMA) has been selected by USATHAMA to be the host installation for this demonstration. Preparatory tasks include selection of a suitable site at RMA for the demonstration, pre-test assessment of contamination at the selected site, and preliminary design of a Hot Gas Decontamination System for the site.

This report presents the results of a site-selection survey performed by Battelle Columbus Laboratories. Candidate structures for the full-scale demonstration include thirteen buildings (Table 1) that have been previously identified[3,4] as likely to have had contamination by chemical warfare agents: either distilled mustard (HD) or nerve agent Sarin (GB).

Initially, four earthen-covered chemical munitions storage igloos (Buildings 1605, 1608, 1609, 1610) were identified as possible candidates for the Hot Gas Decontamination Process demonstration because of their ideal size, shape and construction. However, based on record investigation and on interviews, it appeared that there were no incidents of chemical agent spills in the buildings, so they were dropped from further consideration. Similarly, the former Toxic Storage Yard in Section 30 was also a candidate because of the known contamination present. It was dropped from the survey when it was discovered that there are no structures in the Yard to

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3 R.L. Stollar and Associates, et al. September, 1987. Draft Vol. II, Structure Profile Database Survey. Ebasco Services, Inc., for Program Manager for Rocky Mountain Arsenal Contamination Cleanup.

4 R.L. Stollar and Associates, et al. May, 1988. Draft Final Vol. II, Structure Profile Database Survey. Ebasco Services, Inc., for Program Manager for Rocky Mountain Arsenal Contamination Cleanup.

TABLE 1. CANDIDATE BUILDINGS FOR HOT GAS DECONTAMINATION PROCESSES DEMONSTRATION, ROCKY MOUNTAIN ARSENAL

BLDG NO.	TITLE	AGENT OF INTEREST[a]	JURISDICTION
1501	GB Production	GB	Army
1506	GB Storage (tanks)	GB	Army
1601	GB Munitions Filling	GB	Army
1601A	Ammunition Demilitarization Facility (GB Pump Room)	GB	Army
1606	GB Cluster Assembly (explosion cubicles)	GB	Army
1611	Demilitarization Facility	GB, HD	Army
412	H Filling, Manufacture, and Storage	H, HS	Shell
417	H Decontamination Pit	H, HS	Shell
422	H Manufacture/Aldrin Production	H	Shell
426	H Disposal Reactor	H	Shell
514	L/HD/Pesticide Manufacturing	HD	Shell
536	Ammunition Demiliterization Facility/Crude H Storage	HD	Army
537	Thaw House (HD Demilitarization Facility)	HD	Army

a GB = nerve agent Sarin
H = crude mustard (chemical agent)
HS = mustard with dissolved sulfur (chemical agent)
HD = distilled mustard (chemical agent)
L = lewisite (chemical agent)
Aldrin = organochlorine pesticide

decontaminate. There may be more contaminated structures in the 400 building series in the South Plants area, but the scores of the structures ranked here are indicative of the suitability of the other buildings for the Hot Gas Decontamination Process demonstration.

Site selection criteria were established and each candidate structure was assessed for its suitability for the field demonstration. Sites have been ranked, and recommendations of suitable candidates for the first demonstration and later demonstrations are presented in subsequent sections of this report.

METHODOLOGY

The site-selection survey recommendations are based on reviews of historical literature and records about contamination at RMA, interviews with people that are knowledgeable about past operations at RMA, review of building plans and drawings, review of chemical analysis studies of agent-contaminated building and environmental media, and visual inspection of the candidate facilities.

SITE SELECTION CRITERIA

Site selection criteria for the Hot Gas Decontamination Process field demonstration fall into four broad categories: institutional, informational, chemical, and engineering. Within these four categories, 15 criteria are differentiated. Each candidate was rated for its suitability against each of the 15 criterion on a scale of 1 to 5: 1 = excellent, 2 = good, 3 = fair, 4 = poor, and 5 = very poor. Each criterion is described below.

INSTITUTIONAL CRITERIA

Institutional Accessibility. On RMA, the U.S. Army has historically leased parts of its industrial complex to tenants. At the present time, there are several buildings in the South Plants area that are leased to Shell Chemical

Company. To avoid potential legal involvement, it is thought best at this time to perform the Hot Gas Decontamination Process demonstration on buildings that are under Army jurisdiction.

Ease of Compliance with Army Safety Regulations. For this research and development demonstration, it is most desirable to choose a site where contamination history is known, the status of decontamination activities is documented, the physical hazards to workers can be minimized, and the down-wind hazard to the public is zero. The ease with which approvals can be obtained in a timely manner is an important consideration.

Ease of Compliance with Environmental Regulations. The ease with which the demonstration can be performed without endangering the public or the environment, is important. Because of the present status of RMA under CERCLA actions, environmental permitting may not be necessary, but all laws pertaining to environmental protection must be met.

INFORMATIONAL CRITERIA

Completeness and Accuracy of Historical Information. It is highly desirable to have a complete and accurate history of the site. Such information includes: exactly where spills occurred, the type of agent and other chemicals that may be present, the magnitude of the contamination to expect, and the decontamination history of the building.

Availability and Completeness of Drawings. In order to set up a Hot Gas Decontamination System, blue prints and "as built" drawings are necessary. Unrestriced access to drawings is desirable. Many RMA buildings have been used for multiple operations involving different agents and pesticides, and process equipment has been modified accordingly. A candidate building should have its history well-documented in drawings.

CHEMICAL CRITERIA

Probability of Presence of Agent and/or Agent Breakdown Product. The candidate site should have a good possibility of having residual agent present in concrete and process equipment. For example, it is well documented that HD can persist in the environment and in concrete[5]. On the other hand, nerve agent GB breaks down much more easily in the environment and is much less persistent in concrete than HD. It is possible, however, that GB could persist in process equipment and piping or that GB breakdown products might persist in concrete.

Ease of Verification of Agent Decontamination after Hot Gas Test (Verifiability and Sensitivity of Detection of the Analytical Methods). It has been demonstrated that both HD and GB react chemically with concrete. In results of previous analytical studies of the interaction of agent and concrete, it has been demonstrated and verified that trace amounts of HD can be recovered from concrete[5]. GB has never been reliably recovered from concrete, and the chemistry and kinetics of its interaction with concrete are not known. Therefore, the effectiveness of the Hot Gas Decontamination Process can be verified more conclusively by using HD rather than GB.

Freedom from Spurious Chemical Interference. It would be most desirable if a minimum number of different chemicals are potentially present in a candidate building and that the decontamination solutions used in its history are known. This should simplify interpretation of analytical results.

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5 Zamejc, E.R., et al. June, 1985. Report of Novel Decontamination Techniques for Chemical Agent (GB, VX, HD) Contaminated Facilities, Phase II: Laboratory Evaluation of Novel Agent Decontamination Concepts. Battelle Columbus Division for U.S. Army Toxic and Hazardous Materials Agency, Report AMXTH-TE-TR-85012.

ENGINEERING CRITERIA

Physical Accessibility. The building or part of the building should be easily accessible so that the equipment for the decontamination system can be configured with a minimum of modification to the structure. The area should be easily accessible to workers in order to minimize safety concerns.

Suitability of Building Materials for Decontamination by the Hot Gas Process. Building materials must not be flammable. Glass and flammable materials such as wood and plastic must be removed prior to decontamination. A minimum of such materials is desirable in a candidate site for a demonstration test.

Size and Simplicity of Form. The candidate site should not be greater than one story in height or contain complicated equipment or structures that are difficult to sample or assess. For this first demonstration, the shape should be fairly simple to minimize engineering considerations and ensure adequate and uniform heating.

Ability to Insulate/Isolate Structure. It is most desirable to be able to isolate the structure from its surroundings so heating can be controlled. In addition, it is desirable to be able to measure any contamination that may migrate outward from the structure during heating, and that any such contamination could be easily contained.

Variety of Non-flammable Building Materials Available to be Sampled. In order to obtain a comprehensive evaluation of the Hot Gas Decontamination Process, it would be desirable to have many different kinds of contaminated building materials and process equipment available to assess contamination before and after the test.

Ability to Perform Pre-test and Post-test Contamination Assessment Sampling. The candidate structure must be large enough that both pre- and post-test samples can be collected.

Availability of Utility Support. Basic utilities such as electricity, water, and sewer should be available in or near the candidate building.

RESULTS

Table 2 shows the selection criteria and the status of each candidate structure with respect to the site selection criteria. Descriptions of the buildings, and their use and spill histories are taken from literature review documents[3,4,6]. The written historical information is supplemented by selected interviews with RMA present and past employees. Visual inspection by Battelle and RMA personnel on June 24, 1988 confirmed the location and condition of the candidate sites. The present suitability of candidates for the Hot Gas Decontamination Process demonstration was evaluated at that time.

Brief descriptions of each candidate building are given below.

BUILDING 1501 - GB PRODUCTION

Building 1501 is a 79,400 ft^2 facility built in 1952 for the production of bulk GB (nerve agent Sarin). The building is in good condition, and its equipment is well-housed and free from rainwater intrusion. It is located in the North Plants complex, and is 250 ft east of Road NC-4, west of Building 1704, and east of Building 1601. The structure, whose height is approximately equivalent to eleven stories, is divided into six operational levels, with numerous embayments.

The building is maintained on standby status by the U.S. Army. Institutional access may be difficult, because the future use of Building 1501 has not been decided at this time.

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6 U.S. Army. December, 1975. Final Report, Project Eagle I Bulk Mustard Demilitarization. Office of the DA Project Manager for Chemical Demilitarization and Installation Restoration.

TABLE 2. COMPARISON OF CANDIDATE STRUCTURES WITH SITE SELECTION CRITERIA

Site Selection Criteria	Building Candidates												
	1501	1506	1601	1601A	1606	1611	412	417	422	426	514	536	537
Institutional Criteria													
Institutional Accessibility	4	2	2	2	2	2	3	3	5	5	5	1	1
Ease of Compliance with Army Safety Regulations	4	2	4	4	4	3	5	5	5	5	5	2	2
Ease of Compliance with Environmental Regulation	3	1	2	2	2	3	4	4	5	5	5	2	1
Informal Criteria													
Completeness and Accuracy of Historical Information	3	2	3	3	2	2	5	5	5	5	3	5	1
Availability and Completeness of Drawings	5	2	2	2	2	2	2	5	5	5	5	2	1
Chemical Criteria													
Probability of Presence of Agent and/or Agent Breakdown Product	3	2	3	2	2	2	2	2	2	4	2	4	1
Ease of Verification of Agent Decontamination	4	4	4	4	4	4	2	2	2	2	3	1	1
Freedom from Spurious Chemical Interference	3	2	2	2	2	4	4	4	5	5	5	4	3
Engineering Criteria													
Physical Accessibility	4	2	4	4	4	4	5	5	5	2	4	2	1
Suitability of Building Material for Decontamination by the Hot Gas Process	3	1	3	3	2	4	5	2	4	2	3	2	1
Size and Simplicity of Form	5	1	5	5	3	5	4	3	4	2	3	3	1
Ability to Insulate/Isolate Structure	4	1	4	4	2	4	4	2	4	2	4	2	1
Variety of Non-Flammable Materials Available to be Sampled	3	1	3	3	2	2	4	5	4	4	3	2	1
Ability to Perfrom Pre-test and Post-test Contamination Assessment Sampling	4	2	4	3	3	2	4	3	4	2	4	2	1
Availability of Utility Support	2	2	2	2	2	2	3	5	5	3	2	4	1
Score	54	27	47	45	38	45	59	55	64	53	60	38	18

Legend
1 = Excellent
2 = Good
3 = Fair
4 = Poor
5 = Very Poor

The information record is difficult to assess for completeness and accuracy. Spills of GB, methylphosphonic dichloride (dichlor), xylene, and hydrofluoric acid are documented; many spills of GB occurred during operations. Drawings of the building and process piping are classified, which restricts information on engineering design for the Hot Gas System demonstration.

It is possible that GB contamination in the building is present, especially in the numerous pieces of process equipment contained in the area. However, GB has not been successfully recovered from spiked concrete samples in the laboratory, thereby introducing uncertainty about the analytical methods used to monitor decontamination of the structure. This concern would apply to any GB-contaminated site that might be considered as a candidate for the demonstration test. Building 1501 is large enough that areas where only one chemical was spilled may be found, which would limit the number of unexpected chemicals in the analysis.

The lack of good fit with engineering requirements for the demonstration is the major problem with Building 1501. Physical accessibility is very poor. During the June 24 site visit, it was possible to enter the building, but the second floor embayments were inspected through the windows. The building is divided into several stories, accessible both by stairs and by an elevator that is not serviced, which poses a logistical problem of putting the Hot Gas System in place. The stairs restrict access, increasing problems with safety considerations.

The building and rooms are constructed of poured concrete, but each embayment is packed with process equipment that may have flammable hoses, oils, etc. Glass windows would have to be removed, and the open area sealed in preparation for the demonstration. The building is reported to contain 90 to 100 large chemical-process vessels connected to piping, pumps, valves, and fittings.

The building is too large to decontaminate as a single unit in the demonstration program. Decontamination could take place in isolated bays

inside the building, which would facilitate containment of emissions, but the individual bays are also quite large and complex. Appropriate utilities are available to operate the Hot Gas Decontamination Process.

Building 1501 may be a good candidate for Hot Gas Decontamination after the process is a proven technique, but the building is considered to be too large and complex for the proposed demonstration.

BUILDING 1506 - GB STORAGE.

Building 1506 is located 30 ft east of Road NS-4 and west of Building 1501 in the North Plants complex. It is a reinforced concrete structure approximately 176 ft long by 52 ft wide consisting of five rooms above grade, and ten underground vaults, each containing a 10,000 gal storage tank. It was built in 1953 for use as a storage vault for bulk GB agent produced in Building 1501.

Institutional accessibility to Building 1506 is good, with jurisdiction by the Army.

There is not a lot of information on decontamination history of the vaults or structural modifications for various operations. In 1979, the building was used to inspect leaking Weteye bombs. After operations ceased, the facilities and equipment were decontaminated. The disassembly room was also cleaned but could not be certified for 3X (surface decontaminated, and verified by monitoring that vapor levels do not exceed 0.003 mg/m^3 for mustard agents or 0.0001 mg/m^3 for GB). Its present status is not known. Drawings are available and are not classified.

Information available shows that GB was the only chemical stored in the tanks in the building, both during production operations and during demilitarization operations. There have been several spills of GB recorded, and in October 1974, vaults 5121, 5119, 5120, and 5118 were found to be agent-contaminated. Records show that in 1974 six of the storage tanks had water in them, but the status of the other four is not known. When the

building was visited on June 24, water was standing in the vaults above the top of the tanks, which means at least 12 ft of standing water was present; the water level has been higher. Breakdown products of GB, but no GB, have been discovered in water samples collected from the vaults recently. GB breaks down very quickly in water, so if the tanks are all full of water there may be no GB present.

From an engineering standpoint, the vaults would be good candidates for a demonstration project. The building and the vaults are physically accessible with access to the vaults through manholes that are open to the ground surface. Sampling could possibly even be done by remote methods, increasing safety factors.

No flammable materials are present. The size of the vaults is appropriate and the structure is simple. Each vault contains one 10,000 gal storage tank made out of carbon steel, 8 ft in diameter by 26 ft in length. Each tank is mounted horizontally on concrete piers. Two tanks contain carbon steel centrifugal pumps, and two others are equipped with agitators. Each vault contains a sump and a vacuum suction line to recover spilled GB. Two other sumps, each provided with a cast iron pump, are in the structure: one in the corridor and one in the filling room.

The vaults are isolated and insulated by the surrounding soil. Concrete and steel building materials plus tanks and process equipment (but not too much process equipment) are present. Utilities are available.

The major drawback to using the vaults is the presence of groundwater. They would have to be dewatered by pumping, and the water level controlled during the demonstration. Well points or a collection sump and submersible pump might be required to dewater the area around the building.

Building 1506 seems to be a good candidate for the Hot Gas Decontamination Process demonstration. The uncertainty, however, of contamination status and the water problem are deterrents for the initial demonstration.

BUILDING 1601 - GB MUNITIONS FILLING

Building 1601 is a single-story structure of approximately 68,594 ft^2, with dimensions of approximately 600 ft long by 121 ft wide. It is located in the North Plants area west of Buildings 1501 and 1506, and directly south of Building 1606. It was built in 1951-1953, and began operations in 1953. It houses three automated fill lines, and a free-standing, 8-in. fill machine.

The building is institutionally under Army control.

Of major interest in the building are the fill lines. During the 1950s these fill lines were used to fill munitions with GB, but in 1969, were put on standby. Although several spill events are recorded, the amount of spilled agent and cleanup activities are not well documented. GB and M34 bomb demilitarization/disposal ended in 1976. In 1977, the building was shut down and the heat was turned off. No other projects have been conducted in the building since that time. Maintenance activities, such as repairing a leaking roof in 1983, have been carried out. Drawings of the building are available.

The fill lines are complex equipment, and would have to be divested of glass and flammable materials in preparation for a demonstration. The lines sit on the concrete slab floor of the building, are free standing, and could be isolated for a test. Containment of vapors when the fill line is opened for sampling, however, would be difficult and would require extensive safety considerations. Pre- and post-test sampling would be difficult. The free-standing machine is also a candidate for future testing, but it presents the same difficulties as the fill lines.

BUILDING 1601A - AMMUNITION DEMILITARIZATION FACILITY (GB PUMP ROOM)

Building 1601A is located in the North Plants complex adjacent to Building 1601. The structure has approximately 2310 ft^2 of floor space, is 71 ft long by 32 ft 8 in wide, and is approximately two stories in height.

Institutional access to Building 1601A is good for the Hot Gas Decontamination Process demonstration, because the building is under Army control.

The written historical information compiled on Building 1601A is fairly complete. The building was constructed by the Army at the start of its GB demilitarization operations to function as a ton-container unloading and storage space, and to house the pumps used to transfer GB from various demilitarization/downloading operations to Building 1501 where it was neutralized. Building 1601A has been inactive since 1980. Spills of GB in Building 1601A and 1601 in 1962 and 1963 were caused by failure to reroute the valves which contained recirculated GB for blending and sampling. In January 1963, approximately 400 gallons of GB backed up in the equipment and spilled out onto the floor in Building 1601A. Drawings of the room and equipment are readily accessible.

During agent operations in the 1970s, Building 1601A was always considered "hot", and monitoring equipment set outside the door of Building 1601A often detected trace amounts of GB. Based on the historical information available, GB agent and/or breakdown products could possibly be found in Building 1601A today. It appears, from visual inspection, that the structure has been decontaminated, presumably with caustic, because a thick layer of a white substance blanketed the floor and equipment.

Physical access to the building is restricted because it must be entered from inside Building 1601. Building 1601A was inspected from windows during the site visit of June 24, but entry was not possible. Large quantities of glass and flammable materials are present. The building is large and houses complex industrial process equipment, which makes it a poor

candidate for the first Hot Gas Decontamination demonstration. The whole building would have to be insulated and isolated for the demonstration.

Although the building is a candidate from a chemical standpoint, the engineering requirements are not met for the test demonstration.

BUILDING 1606 - CLUSTER ASSEMBLY BUILDING

Building 1606 is located in the North Plants complex. It is parallel to, and lies 130 ft west of, Road NS-4 between Building 1601 to the south and Building 1607 to the north. It is a single-story structure approximately 600 ft by 102 ft by 30 ft, with an area of approximately 64,000 ft^2 (estimates vary due to inclusion of building additions). It is divided into north and south bays that are separated by an explosion-proof section.

The building, shut down in 1977, continues to be maintained by the Army.

The information available about Building 1606 is not very complete. Building 1606 was originally constructed in 1951 by the Army for the production and packaging of GB-filled munitions. Several operations have been performed in Building 1606: M34 cluster bomb assembly (1953 - 1955); M55 rocket filling and assembly (1960 - 1964); microgravel and anti-intrusion (XM47) mine assembly (1967 - 1968); filling of M139 bomblets (1965 - 1970); and demilitarization of M34 cluster bombs (1973 - 1976). All operations except the XM47 mine assembly involved GB. Extensive releases of liquid GB agent occurred in the two cubicles used for M34 cluster bomb demilitarization. In May, 1974 there were two minor explosions inside the explosion cubicles. GB was released, but was contained inside the cubicles. Neither exact locations and times of spills, nor decontamination history was detailed in the historical documents reviewed. Drawings of the building are available.

The possibility of residual GB contamination in the cubicles is high.

During the June 24 site visit, Building 1606 was entered. The explosion-proof section is made of reinforced concrete, 89 ft by 102 ft by 57 ft. It contains eight cubicles, two corridors, four fuse rooms, and two plenum chambers. Of particular interest for the Hot Gas Decontamination Process demonstration are the two explosion containment cubicles used in the M34 program. It was not possible to enter these cubicles during the site visit. The cubicles have two-ft-thick metal-reinforced and metal-lined walls. The tops of the cubicles are open gratings leading to the expansion plenums above. Although the structure would be a good size and shape to decontaminate, it is reported that the Versitran machines are still in place. These are very complex, with several thousand fittings in each machine. The machines are hydraulically operated and may still contain oil, requiring extensive building preparation prior to decontamination.

The cubicles are candidates for Hot Gas Decontamination in the future, but are too large and contain too much complex equipment for the current task.

BUILDING 1611 - DEMILITARIZATION FACILITY

Building 1611 is part of the North Plants complex at Rocky Mountain Arsenal. It is located north of Building 1703 and south of Building 1616 in Section 25, approximately 2,750 ft south of 9th Avenue and 3,480 ft east of "D" Street.

Building 1611 was built in 1953 by the Army as a warehouse to support GB production operations in the North Plants area. It also served as an instrument shop and a gymnasium. The dimensions of the original two-story concrete-block structure were 171 ft 2 in by 61 ft 4 in by 24 ft. Its area was 10,498 ft^2.

Expansion and conversion of Building 1611 to accommodate demilitarization operations for the GB-filled M190 ("Honest John") warhead and M139 bomblet disposal project began in 1974. The new additions included a demilitarization area measuring 112 ft 4 in by 63 ft 6 in, a furnace area

measuring 53 ft 10 in. by 55 ft, and a GB storage room measuring 20 ft 2 in by 13 ft. The demilitarization area consisted of an observation room, control room, punch and drain room, disassembly room, showers, dressing rooms, and air locks. The furnace area consisted of the decontamination furnace room, deactivation furnace room, and deactivation furnace conveyor room. The GB storage room contained a GB storage tank and two pumps.

The facility was further modified from 1977 to 1979 to accommodate the disposal of chemical agent identification and training sets (CAIS). An afterburner, quench, electrostatic precipitator, glove box disassembly system, and shrouded conveyor were added.

A total of 1761 CAIS were destroyed in the pilot program. An additional 19,697 sets containing mustard, lewisite, adamsite, potassium cyanide, triphosgene, chloroscetophenone, chloropicrin, and phosgene were incinerated in the second stage program which was conducted from May 8, 1981 to December 22, 1982. Waste generated from the incineration and decontamination program included furnace waste (burned cans, crushed glass, and ash), spray-dried salts (sodium carbonate and sodium chloride), and electrostatic precipitator residue (fly ash, salts, and heavy metals). Furnace residue, primarily arsenic-contaminated charcoal dust, as well as other waste materials were packaged in 55-gallon drums in Building 1611 and stored at RMA pending disposal.

A DDT-contaminated small arms demilitarization program was initiated on January 26, 1983 and completed by June 3, 1983. During operations, 851 boxes, each containing approximately one short ton of ammunition, were incinerated. Each ton of ammunition was contaminated with an estimated 5 pounds of DDT. The furnace feed room of Building 1611 was partitioned from the disassembly room for the DDT disposal project. Chemical waste generated by the demilitarization of DDT-contaminated small arms munitions was incinerated in the decontamination furnace and afterburner to ensure final destruction of the DDT. Exhaust gases from the afterburner then passed through a spray quench, electrostatic precipitator and scrubber before being released to the atmosphere. The spent scrubber solution was processed to a

dry salt in the spray dryer facility, Building 1703, and then placed in 55-gallon steel drums.

An adamsite (DM) demilitarization program began on June 6, 1983 with pilot testing, and was completed July 1, 1983. This program included disposal by incineration of DM grenades and bulk DM. Grenade demilitarization operations began July 5, 1983 and were completed during the week of August 22, 1983. Bulk DM demil operations started August 30, 1983 and were completed by June 13, 1984. During these operations 156,600 grenades, 939 drums of bulk DM (gross weight of 465,139 pounds), 200 DM capsules, 24 DM candles, and 85 drums of DM tablets were demilitarized. Decomposition by products of the DM incineration process include water, carbon dioxide, ammonia, hydrogen chloride, arsenic pentoxide, and arsenic trioxide. The scrubbing system removed ammonia and hydrogen chloride from the gas stream. The arsenic oxides were removed by the electrostatic precipitator.

Building 1611 is not in use at this time but it is under Army control. The facility is not considered a good candidate for the hot gas decontamination process testing because of its large size, structural complexity, and the presence of many types of process equipment including two furnaces, an afterburner, quench, electrostatic precipitator, conveyors, air-lock doors, differential pressure calls, automated heating and ventilation fans and dampers, and personnel support facilities including shower lockers and lunchroom. The most likely chemical contaminants are arsenic compound residues in the deactivation furnace room, but these would not be expected to volatilize at the temperatures used in the hot gas process.

BUILDING 412 - H FILLING, MANUFACTURE, AND STORAGE.

Building 412 is located in the South Plants manufacturing area, approximately 380 ft east of "D" Street, 1230 ft south of December 7th Avenue and west of Building 422. It is a two-story building, 149 ft long by 71 ft wide, with single-story additions. The floor area is approximately

21,536 ft^2 (24,414 ft^2 with additions). The foundation of the building is concrete, the frame is wood, the walls are wood with celo-siding, and the roof is built-up asphalt and felt. Its companion waste-disposal facilities include Buildings 414, 415, 416, and 417. A twin complex, consisting of Building 422 and its disposal facilities, exists in the same area.

Building 412 was constructed by the Army in 1942 as a mustard chemical agent (H, HS) manufacturing, munitions filling, and storage building. The building has been used for several operations. In 1942 - 1943, crude mustard (H) chemical agent was produced. Maintenance during this time included periodic decontamination of process equipment with chlorinated carbon tetrachloride and a hot caustic and soda-chlorine treatment. The resultant solution was disposed of in Building 417, the decontamination pit, where it was neutralized with caustic and bleach, and piped to Basin A via the chemical sewer. No information about occurrences of leaks or spills of H during this operation is available. The building was put on standby by the Army in 1945.

The plant was leased to Julius Hyman and Company sometime between 1949 and 1952. Starting in 1952, Building 412 was used to produce methylphosphonic dichloride (dichlor), a feed chemical for GB production. Much of the equipment in the building degraded dramatically during the production of this severely corrosive chemical, and several piping and sewer leaks were reported. The Army resumed control of Building 412 in 1956 and put it on standby status. The building was scheduled to be demolished in the 1980s.

Building 412 was inspected during the June 24 site visit, and was found to be in very poor condition. The wood construction of Building 412, its size, and its dilapidated condition preclude its suitability for the Hot Gas Decontamination Process demonstration.

BUILDING 417 - H DECONTAMINATION PIT

Building 417 is located in the South Plants area west of Building 412, approximately 100 ft east of "D" Street, and 1220 ft south of December 7th Avenue. It is an underground concrete pit measuring 9 ft 6 in by 6 ft by 6 ft 3 in deep, and was once covered by a steel grill. No above-ground structure encloses it. It was connected to the rest of the H manufacturing plant facilities by pipe and had an overflow connection to the chemical sewer, which drained to Basin A.

Information about the use and contamination status of this pit is largely unknown. This pit was part of a crude mustard (H) manufacturing plant built in 1942, and was used for neutralization of wastes from Building 412. It was used during the H-production operations from 1942 to 1943. Although dichlor was produced in Building 412 during the early 1950s and Building 417 was leased to Julius Hyman and Company in 1952, the use of Building 417 for this operation is not documented. The building has been under the control of the Army since 1956. No drawings of the pit exist.

Only the foundation of Building 417 remains. The approximate location was inspected during the June 24 site visit. Although there are no flammable materials present, there is only concrete to decontaminate, and no process equipment, tanks or steel construction material are available for testing. The pit is small for the projected set-up of the demonstration system. There are no utilities in the building.

Building 417 may be a candidate for future decontamination activities, but is considered a poor choice for the present demonstration program.

BUILDING 422 - H MANUFACTURE/ALDRIN PRODUCTION

Building 422 is located in the South Plants complex, approximately 670 ft east of "D" Street and 1240 ft south of December 7th Avenue. It is east of Building 412. The building originally measured 71 ft by 149 ft 4 in and was two stories high, with two small single-story additions. Only the south

and central portions of the original building remain. A new, two-story, steel and asbestos building was built to replace the north part of Building 422 which was razed (date unknown). Companion disposal buildings to Building 422 were Buildings 424, 425, 426, and 427.

The building is currently leased to Shell Chemical Company, posing institutional accessibility problems.

Building 422 was built in 1942 as a duplicate plant to the Building 412 complex, and housed identical H manufacturing operations. The scant historical information available for Building 422 indicates that the building was used for H production from 1942 to 1943, then decontaminated and put on standby by the Army in 1945. Julius Hyman and Company may have leased the building as early as 1945, but more likely began leasing it in 1950. The pesticide Aldrin was produced in the reactor part of the building from 1950 to 1956. The storage tank section of the building was used to store Aldrin and unidentified raw materials. The filling section was used at least until 1975 for the drumming of chemicals, including Pyrdin (an insecticide) and possibly Nemagon-E (a soil fumigant). The building is presently in the Shell Chemical Company's lease holding.

It is possible that H contamination remains in the old part of the building and in the sewer lines, but no precise records of spills are available. The pesticide production and accompanying contamination adds a measure of uncertainty to the chemical identification process necessary to evaluate the effectiveness of the Hot Gas Decontamination Process.

The condition of the original part of the building is very poor and poses physical accessibility problems. Building 422 was inspected on June 24 and was found to be of unsuitable construction for the Hot Gas Decontamination Process. The building has a concrete foundation, wood frame, wood walls covered with celo-siding, and a flat wood roof covered with asphalt and felt.

Building 422 is considered to be a poor candidate for the Hot Gas Decontamination Process demonstration because of the Shell Chemical Company lease, the unsuitability of construction, and the complexity of chemical operations conducted there.

BUILDING 426 - H DISPOSAL REACTOR

Building 426 is located in the South Plants complex, approximately 860 ft east of "D" Street, 1260 ft south of December 7th Avenue, and east of Building 422. It contains an 8,245-gallon capacity steel pressure tank, 10 ft in diameter by 15 ft high.

The building has been leased by Shell Chemical Company since 1952, which means institutional inaccessibility for the Hot Gas Decontamination Process demonstration program.

Building 426 was built in 1942, and was used to neutralize batches of H produced in Building 422 that did not meet specifications. Information about spills and decontamination history during the H production operations of 1942 - 1943 is nonexistent, and the history of its use after 1950 is not historically documented. No drawings exist for Building 426.

By its description, Building 426 appears to be a good candidate for the Hot Gas Decontamination Process from an engineering standpoint. During the site visit of June 24, however, the building was not located successfully, so its present condition is not known.

Coupled with the lack of historical information and the lease arrangement with Shell Chemical Company, Building 426 is not a recommended candidate for the Hot Gas Decontamination Process demonstration program.

BUILDING 514 - L/HD/PESTICIDE MANUFACTURING

Building 514 is located in the South Plants area, approximately 420 ft south of December 7th Avenue and approximately 1070 ft east of "D" Street.

It is located east of Building 512, west of Building 529, and north of Building 516. Building 514 is a large, three-story structure of post- and beam-concrete construction, with a floor area of approximately 17,280 ft^2.

Building 514 is presently leased by Shell Chemical Company, which makes it an undesirable candidate for the proposed demonstration of the Hot Gas Decontamination Process, because of institutional accessibility.

The information available about Building 514 seems fairly complete. The building was constructed by the Army in 1942 to house reactor vessels of the lewisite chemical agent (L) manufacturing plant, which operated in 1943. From 1945 to 1946, the building was used for storage of distilled mustard (HD) during the HD distillation operations. Crude mustard was pumped to holding tanks in building 514 and "washed" with water. The washed mustard was then pumped to holding tanks, and the contaminated wash water was discharged to a decontamination pit located outside of Building 514 near the southeastern corner of the Building 514

In 1947, Building 514 was leased to Julius Hyman and Company for the production of the pesticide Chlordane, and in 1951 Shell Chemical Company took over the lease. In the ensuing years, Building 514 has been used by Shell in the manufacture at least seven pesticides. Operations were ended in 1982.

Possible contaminants from the lewisite operation include mercuric chloride catalyst, arsenic trichloride, thionyl chloride, and lewisite. Other contaminants may be present from the pesticide manufacturing. The many chemical operations conducted at this building greatly increases the possibility of multiple contaminants, besides HD.

Building 514 was inspected during the June 24 site tour. There were many glass windows that would have to be removed prior to testing. The building was deemed too large (with its three stories) and too complex from an engineering standpoint for the Hot Gas Decontamination demonstration. The building has a concrete foundation and floor, structural clay tile

walls, and a corrugated asbestos panel roof. Two penthouses are located on the roof. Many pieces of process equipment could be seen through the windows. The building looked dilapidated.

Building 514 was not considered a good candidate for the Hot Gas Decontamination Process demonstration because of its engineering unsuitability, the multiplicity of chemicals potentially present, and its current status in the Shell leasehold.

BUILDING 536 - AMMUNITION DEMILITARIZATION FACILITY/CRUDE MUSTARD STORAGE.

Building 536 is located in the South Plants area, approximately 1360 ft east of "D" Street, 500 ft south of December 7th Avenue, and east of Building 528. Building 536 encompasses approximately 6128 ft^2, with dimensions of 48 ft 4 in by 84 ft 4 in. There are two ceiling elevations: 15 ft and 26 ft.

Institutionally, access to Building 536 would not be a problem for the Hot Gas Decontamination Process demonstration because it is under Army control. The Army has maintained control of the building throughout its history.

The information about the operations conducted in Building 536 is sketchy. It was built by the Army in 1945 as a crude mustard (H) storage facility, and there was involvement in the HD distillation operations of the 1940s. In the early 1970s, the building was used to house an experimental incineration system (the "Taylor" system), which was to be used for a project (Project Eagle) to demilitarize bulk H and HD. The system failed to meet the criteria for the program, and was abandoned in favor of larger-scale incineration furnaces in Building 538 for the mustard demilitarization operation. Equipment in Building 536 was subsequently modified to support the other incineration system.

Historical information about likely spill locations was not available. The equipment that was potentially HD-contaminated from the 1970s HD

demilitarization operation was reportedly removed from the building and incinerated after that operation ceased. A separate effort by the Program Manager Office of Rocky Mountain Arsenal to confirm this action is underway, but the results are not available at this time.

The building has a concrete foundation with a cement floor, and has cinderblock walls on every side but the south side, which has removable wood panels to facilitate tank and equipment removal. A steel shack and an emissions or ventilation stack are located on the roof deck. The equipment in the interior is purported to be a storage tank, incinerator, scrubber, brine storage tank, spray dryer, bag filter house, salt storage silo, heat exchanger, two cooling towers, and associated support equipment to these items. Some or all of this equipment may not be present. Building 536 was not entered during the June 24 site visit, so the condition of the interior and its equipment was not evaluated.

The major deterrent for using Building 536 for the Hot Gas Decontamination Process demonstration is the uncertainty of HD contamination in the existing structure.

BUILDING 537 - THAW HOUSE (HD DEMILITARIZATION FACILITY)

Building 537 (Thaw House) is located in the South Plants industrial complex, approximately 1440 ft east of "D" Street, 400 ft south of December 7th Avenue, and northeast of Building 536. Building 537 is divided into three parts: the western container unload area, the central thaw rooms, and the eastern chemical unload and transfer area.

The building is under the jurisdiction of the Army, so institutional access is good.

Information about the building's history is fairly complete, and many drawings are available. Building 537 (Thaw House) was constructed in 1945 as part of a crude mustard distillation plant, where H was purified to produce HD, a product of high stability suitable for munitions filling. The

mustard subsequently was pumped to other buildings for storage, or to furnaces in Building 538 for incineration. This building has been used for at least six projects involving mustard production and demilitarization, and was also the site of demilitarization of the cyanogen chloride-filled M-78 and M-79 bomb (1965-66) and phosgene storage container transfer (1976).

Operations involving agents other than HD did not use the receiving tanks in the pit, so the area is relatively free of the presence of spurious agents. The eastern end of Building 537 has a garlic-like odor similar to mustard, although none has been detected above the time-weighted average (TWA) of 0.003 mg/m^3. The presence of mustard breakdown products (dithiane and oxithiane) in the pit area has been confirmed by GC/MS and tandem mass spectrometry[7].

The engineering criteria for the demonstration is fairly well met by the sub-ground concrete pit in the eastern section of Building 537. Physical accessibility for pre- and post-test sampling and Hot Gas Decontamination System configuration is good. The area to be heated is small and confinable, with much of the outside surface surrounded by soil. The pit is a simple rectangular concrete box (50 ft 7 in by 15 ft 8 in by 9 ft 3 in) with a steel-plate covering, and is not a complex shape. Two 2600-gallon tanks are present, along with a smaller vacuum tank. These tanks were used to receive mustard from ton containers or munitions. There is not an overwhelming amount of complex process equipment and piping in the pit. Minimal modification would be required for the demonstration. Utilities, including electricity, water, and sewer, are available.

The pit in the eastern section of Building 537 is an excellent first candidate for the Hot Gas Decontamination Process demonstration.

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7 Bergstrom, M. et al. In Press. Field Sampling a Mustard Demilitarization Facility with the Trace Atmospheric Gas Analyzer (TAGA), Rocky Mountain Arsenal, Colorado. Battelle Columbus Division for U.S. Army Toxic and Hazardous Materials Agency.

RECOMMENDATIONS

Table 3 lists the candidate sites in order of decreasing suitability for the Hot Gas Decontamination Process demonstration at Rocky Mountain Arsenal. The most suitable candidate site is the concrete pit in Building 537, due to the appropriateness of its size and shape, relatively well-known historical use, and the possibility that HD and HD-breakdown products exist. The second-ranking candidate is Building 1506, the GB Storage Tank facility, which exhibits high engineering suitability and the possibility of GB breakdown products. The drawback for using Building 1506 for this demonstration is that the underground storage tanks would require extensive dewatering before and during the test, which would complicate the demonstration. The third-ranked candidate structure, the explosion cubicles in the GB Cluster Assembly Room (Building 1606), provides a large, but relatively simple area to be decontaminated. It is, however, complicated by the presence of many pieces of process equipment. Building 536, the Ammunition Demilitarization Facility/Crude H Storage building, which tied with Building 1606 for third rank, is a suitable candidate from an engineering point of view, but information is very limited about its history of operations, and it may not contain mustard-contaminated equipment or areas.

Buildings 1601A, 1601, and 1501, all used for GB operations, may be suitable candidates for large-scale demonstrations of the Hot Gas Decontamination Process, but are too large and contain too much process equipment to be considered seriously for this test program. For similar reasons, Building 1611 which has a history of multi-chemical-agent use, is not an attractive candidate for the propsced demonstration. Buildings 426, 417, 412, 514, and 422 are either too complex, too dilapidated, or too unknown to be good candidates. Buildings 514, 422, and 426 are currently leased to Shell Chemical Company, which precludes their use in this demonstration program of the Hot Gas Decontamination Process.

TABLE 3. RANKING OF CANDIDATE BUILDINGS FOR HOT GAS DECONTAMINATION PROCESS DEMONSTRATION

RANK	BLDG NO.	CANDIDATE	SCORE
1	537	Thaw Building (HD Demilitarization Facility)	18
2	1506	GB Storage (Tanks)	27
3	1606	GB Cluster Assembly (Explosion Cubicles)	38
3	536	Ammunition Demilitarization Facility/ Crude H Storage	38
4	1601A	Ammunition Demilitarization Facility (GB Pump Room)	45
4	1611	Demilitarization Facility	45
5	1601	GB Munitions Filling	47
6	426	H Disposal Reactor	53
7	1501	GB Production	54
8	417	H Decontamination Pit	55
9	412	H Filling, Manufacture, and Storage	59
10	514	L/HD/Pesticide Manufacturing	60
11	422	H Manufacture/Aldrin Production	64